Report on the PhD thesis by Michal Wlodarczyk

Michal Wlodarczyk's thesis "Approximation algorithms: new results for stochastic and parameterized problems" is a very impressive work both in terms of breadth and depth. In particular, Michal presents novel and interesting techniques for handling stochastic problems, i.e., to deal with uncertainties in the input. In what follows, I describe my opinions of the thesis with respect to results, quality, and presentation. I then give a short summary motivating my recommendation: I clearly deem the thesis as sufficient to grant a PhD. My own expertise is in theoretical aspects of algorithms and, more specifically, in the use of convex relaxations for discrete optimization problems which is closely related to two of the three main results of the thesis (and quite related to the third topic).

Results

Michal's thesis takes a modern approach to the well established field of approximation algorithms. Approximation algorithms give a rigorous mathematical way of designing and comparing the quality of efficient algorithms for NP-hard optimization problems. These are problems that are believed to have no efficient exact algorithms. The central question of the field is to understand within what factor an efficient (polynomial time) algorithm can approximate a considered optimization problem. The thesis considers these questions in modern settings. Specifically, it considers and make significant progress on (1) approximating strategies in the case of uncertainties in the input, (2) devising better algorithms for online decision making and (3) designing parameterized approximation algorithms for important graph problems (that is, approximation algorithms that are allowed to be super polynomial in a problem dependent parameter). The results of the thesis are great contributions. Moreover, the solutions and proofs are clean and nice to read. In what follows, I give a brief explanation of the results in each of three papers that thesis is based on.

Paper 1: When the Optimum is also Blind: a New Perspective on Universal Optimization

The problem considered in this part of the thesis is the stochastic set cover problem. In the set cover problem, we have a universe $U = \{1, 2, \ldots, n\}$ of $n$ elements and a collection $C \subseteq 2^U$ of $m$ subsets $S \subseteq U$, each one with an associated cost $c(S)$. In the classic setting the goal is to find a subset of $C$ of minimum total cost that covers every element. In the stochastic version, the set $X \subseteq U$ of elements to be covered is random. The goal is to fix a strategy of minimum cost of the following form: we precompute (without knowing $X$) a mapping $\phi : U \rightarrow C$ where $\phi(u)$ is some set covering the element $u$. Now if an element $u$ should be covered, i.e., $u \in X$ then we cover it using the set $\phi(u)$.

Prior work on this problem has focused on the difference in the expected cost of such a precomputed solution compared to the optimal solution to the problem (computed knowing $X$). This can be seen as an unfair comparison as there is no way for our strategy to do equally good as an optimal strategy that knows the outcome $X$. An important
contribution in this paper is the insight to instead compare the computed strategy $\phi$ with an optimal precomputed strategy. This makes the stochastic problem a traditional approximation algorithms problem. Using a smart "configuration type" linear programming, Michal then reduces the problem to quite standard randomized rounding techniques. This allows him to achieve the same guarantees for this problem as that of the standard set cover problem for various distributions of $X$. These guarantees are tight and the techniques are versatile and generalize to several related problems.

These results were presented at ICALP 2017.

Paper 2: Random Order Contention Resolution Schemes

A contention resolution scheme can informally be described as follows. Given a fractional vector $x \in [0,1]^n$ over $n$ elements, the contention resolution scheme $\pi$ takes a random set $S$ where $i$ is included with probability $x_i$, independently of other elements and outputs a subset $\pi(S) \subseteq S$ that is feasible with respect to some downward closed constraint set such as a matroid or knapsack constraint. The goal is to satisfy the following guarantee

$$\Pr[i \in \pi(S)] \geq c \cdot x_i \quad \text{for every } i,$$

for a $c$ as large as possible. These schemes have turned out to be very important and influential in several applications such as submodular function optimization. Recently, the author of the report together with co-authors, proposed online contention resolution schemes. That is contention resolution schemes that work online, i.e., seeing elements one-by-one and making irrevocable decisions whether to keep it or not. Assuming that items arrive in a random order, Michal's thesis significantly improves these results. Perhaps even more impressively, a new technique is proposed that by far is the most beautiful proof of an online contention resolution scheme for matroids that I have read. One clear indication of the power of this technique is that they are able to obtain better guarantees in some settings than was previously known even in the easier offline setting!

This part of the thesis is a real gem and it has already inspired follow up work. It is of the highest quality and was presented at FOCS 2018, which together with STOC is considered the leading conference in theoretical computer science.

Paper 3: Losing Treewidth by Separating Subsets

This part of the thesis is less directly related to my own work and so I will describe these results more briefly. Here, Michal considers the problem of deleting the fewest vertices/edges in order to make the graph belong to a certain family. This captures many central problems. Examples include vertex cover — delete the fewest vertices so that the resulting graph has no edges and feedback vertex set — delete fewest vertices so that the graph has no cycle. For these kind of problems, Michal gives a general technique for graphs of bounded tree width. This results give improved parameterized approximation algorithms for an impressive set of problems.

These results were presented at SODA 2019 which is the leading conference on theoretical aspects of algorithms.

Quality and Presentation

The thesis is of excellent quality. The results and the techniques of the thesis are very interesting. In particular the results in Paper 2 are great and very original. The algorithm is simpler and better, and the analysis cleaner compared to prior work. I consider this a major contribution. It should also be said that all three papers that the thesis is based on have already been presented at prestigious venues ICALP 2017, FOCS 2018 and
SODA 2019. This is an impressive record.

The writing of the papers is also very good. The introductory chapter is brief and may be hard for a non-expert to understand. Otherwise it is well written with only a few typos.

Summary and recommendation

Michal's thesis constitutes major scientific progress and has been presented at major venues. I deem the thesis as sufficient to grant a PhD. Moreover, mainly based on the outstanding results of Paper 2, I'd also be in favor of granting it "with an honorary distinction."

Sincerely yours,

Ola Svensson